Effectiveness of Foliar Sprays for Control of Diaprepes abbreviatus *L. on Florida Citrus*[*]

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The occurrence of a solitary specimen of the West Indian sugar-cane stalk borer weevil, *Diaprepes abbreviatus* L., in an Apopka, Florida, citrus nursery during September 1964 represented the first record of this insect in the United States (Woodruff, 1964). A survey of the vicinity where this male adult was taken failed to locate more specimens and it was considered a unique find. Inspectors of the State Department of Agriculture's Department of Plant Industry, in the ensuing four years, discovered no additional adults during their routine nursery inspections until, in September 1968, several larvae were collected in soil at the original site.

A continuous survey in an ever-increasing circle outwards from the new find uncovered numerous additional infestations and delineated the outer limits of the infested region. The infested area, including a circumferential buffer zone, is now the target of a cooperative venture initiated by the U.S. Department of Agriculture, Florida State Department of Agriculture, and Florida Citrus Experiment Station to contain and eradicate the pest.

Since this species has been a serious pest of citrus and sugar-cane in the West Indies and is a potential pest of Florida's 377 156 ha (931 249 acre) of citrus (Florida Department of Agriculture, 1968) and 76 221 ha (188 200 acre) net of sugar-cane (Institute of Food and Agricultural Science, 1969), successful control methods employed in the Caribbean islands were considered for the Florida programme. These included biological and chemical control methods, as well as cultural practices, employed with varying success to combat infestations of *D. abbreviatus* in the islands during the present century.

An early decision in the Florida programme was to use a foliar spray to augment soil treatment in a effort to reduce the adult population as quickly as possible. In conjunction with the screening of candidate insecticides as concentrate sprays to select a material suitable for aerial application, compounds were also tested to determine their performance as dilute foliar sprays. This testing procedure simulated treatments that would be applied by tractor-drawn sprayers in citrus groves, providing information on materials and rates that could be used in treatment of citrus plantings inaccessible or prohibited to aircraft because of location. Promising materials might also be recommended for use by home owners.

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Reference to the use of foliar sprays for control of adults is meagre. Lead arsenate, discussed as a repellent by FENNAH (1942), was previously advocated by GREGORY (1938) for the identical purpose on very young nursery stock in St Lucia. WOLCOTT (1948) mentioned that adult beetles may be killed by feeding on foliage sprayed with barium fluosilicate or arsenicals although he had stated earlier (WOLCOTT, 1933) that lead arsenate at the rate of 2·27 kg in 227 lit of water (5 lb in 50 imp gal) was rarely strong enough to kill *D. abbreviatus*. Preliminary tests reported by WOLCOTT (1948) indicated that adults were readily killed by applying one per cent chlordane or one per cent DDD sprays to infested trees. JACKSON (1963) was successful with dieldrin foliar sprays on date palms.

Only one of these, lead arsenate, is recommended for bearing citrus in Florida and is, moreover, restricted to grapefruit varieties at a concentration equivalent to 0·284 kg in 189 lit (0·625 lb in 50 USgal) of water. Review of available literature does not indicate that the remaining pesticides listed in the latest edition of the Florida Citrus Spray and Dust Schedule (FLORIDA DEPARTMENT OF CITRUS, 1970) have been tested against *D. abbreviatus*. The possibility that one or more of these materials might be effective as a foliar spray was therefore investigated. Moreover, several other materials, recommended for citrus in other localities or whose registration for use on citrus is pending, were also evaluated.

MATERIALS AND METHODS

Experiments were conducted in an infested grove near Apopka by caging beetles on the treated foliage of citrus trees. Terminals bearing tender, but fully expanded, young foliage were selected for testing since beetles prefer to feed on the newly developed flush. Prior to dipping in test solutions, all but the three distal leaves were removed from each twig so that the terminal would fit in the 4·5 cm (1·75 in.) diameter, 15 cm (6 in.) long plastic screened cylindrical cage used to hold the beetles on the foliage during the exposure period. The cages, similar to one illustrated by PETERSON (1959), were provided by the Vero Beach Laboratories Inc., Agricultural Research for Farbenfabriken Bayer AG, Germany, located in Vero Beach, Florida. With three exceptions, the test chemicals are designated in *Table 1* by their approved common names. The three compounds that have no approved common names are:

Acarol: isopropyl 4,4′-dibromobenzilate
Folimat: dimethyl S-(N-methylcarbamoymethyl) phosphorothioate
Supracide: S-((2-methoxy-5oxo-Δ^2-1,3,4-thiadiazolin-4yl) methyl) = 0,0-dimethyl phosphorodithioate

A volume of 946 ml (1 USquart) of spray was prepared for each material containing the amount of insecticide proportional to the rate recommended in the Spray and Dust Schedule for 378·5 lit (100 USgal) of dilutes spray. For those materials not appearing in the Spray and Dust Schedule, manufacturers' recommendations were used. The foliage of five terminals was immersed for ten seconds in the test mixture and then permitted to air dry. When the foliage was dry, a pair of mating beetles was caged on each terminal. Untreated terminals were also infested with beetles.

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an insecticide toxic to the weevils.

Table 1. Mortality of D. abbreviatus

Material	*AI* (g
1. Azinphosmethyl 2LC*	1
2. Formetanate 95% SP	2
3. Monocrotophos 3.2E	1
4. Dimethoate 2E*	2
5. Supracide 2E	1
6. Parathion 4E*	1
7. DDT 25 EC	4
8. Folimat 4E	3
9. Carbaryl 80% WP	4
10. Malathion 5E*	5
11. Carbophenothion 4E*	1
12. Malathion 5E*	2
13. Oxydemetonmethyl 2SC*	
14. Lindane 20% EC	
15. Formetanate 95% SP	
16. Mevinphos 4E	
17. Ethion 4E*	
18. Demeton 2SC*	
19. Dioxathion 4E*	
20. Tetradifon 1E*	
21. Diazinon AG500*	
22. Lead arsenate 95% WP*	
23. Hexachlorophene 50E*	
24. Acarol 2E	
25. Chlorobenzilate	
26. Dicofol 4MF*	

*Compounds listed in the 1970 Florida Citru
†Corrected by Abbott's formula
AI Active ingredient

Mortality counts were made at intervals of 24, 48, and 72 h. Beetles were classified as alive, moribund, or dead. Dead beetles exhibited no trace of visible movement when prodded. Moribund beetles were those which were active but unable to stand or which reacted at least feebly to prodding. Four to six materials were evaluated in each test and tests were repeated if mortality exceeded ten per cent in the control population.

Some of the better materials were then evaluated to determine relative persistence of their residues. In this phase of the investigation, individual trees were sprayed to 'run-off' with one chemical and permitted to dry. Ten pairs of beetles were then caged on randomly selected terminals around the circumference of the tree canopy. At weekly intervals, the cages were examined and when both beetles were dead in a cage, they were removed, the cage was relocated on another terminal, and was charged with two fresh, live beetles. During examination, young foliage, developed after chemical treatment had been applied, was pruned to eliminate the chance of its being inadvertently used in the test. This procedure was destined to continue until none of the exposed insects was killed by the residues. The test was terminated, however, at the end of four weeks because the grove in which it was situated was scheduled to receive an aerial application of an insecticide toxic to the weevils.

Table 1. Mortality of D. abbreviatus *exposed to citrus foliage treated with selected pesticides*

Material	*Amount per 378.5 lit*		*Adjusted % mortality†*		
	AI (g)	*Formulation*	*24 h*	*48 h*	*72 h*
1. Azinphosmethyl 2LC*	113	473 ml	100	—	—
2. Formetanate 95% SP	236	249 g	100	—	—
3. Monocrotophos 3.2E	181	473 ml	100	—	—
4. Dimethoate 2E*	226	946 ml	90	100	—
5. Supracide 2E	113	473 ml	90	100	—
6. Parathion 4E*	113	236 ml	70	100	—
7. DDT 25 EC	453	1893 ml	50	100	—
8. Folimat 4E	340	709 ml	90	90	100
9. Carbaryl 80% WP	453	567 g	80	90	100
10. Malathion 5E*	567	946 ml	64	73	100
11. Carbophenothion 4E*	169	355 ml	70	80	90
12. Malathion 5E*	340	568 ml	20	70	90
13. Oxydemetonmethyl 2SC*	113	473 ml	40	80	89
14. Lindane 20% EC	96	473 ml	50	60	70
15. Formetanate 95% SP	59	62 g	40	60	70
16. Mevinphos 4E	28	59 ml	50	50	63
17. Ethion 4E*	169	355 ml	50	50	56
18. Demeton 2SC*	113	473 ml	20	60	56
19. Dioxathion 4E*	113	236 ml	40	50	45
20. Tetradifon 1E*	56	473 ml	20	50	38
21. Diazinon AG500*	226	473 ml	20	40	34
22. Lead arsenate 95% WP*	538	567 g	0	20	30
23. Hexachlorophene 50E*	28	47 ml	30	40	25
24. Acarol 2E	226	946 ml	0	10	13
25. Chlorobenzilate	57	118 ml	20	30	13
26. Dicofol 4MF*	226	473 ml	10	20	13

*Compounds listed in the 1970 Florida Citrus Spray and Dust Schedule
†Corrected by Abbott's formula
AI Active ingredient

RESULTS AND DISCUSSION

Results, corrected for natural mortality by Abbott's formula (Abbott, 1925), are presented in *Table 1* for the three-day period of exposure. Of the 24 pesticides tested, only the ten that produced complete kill in 72 h are considered of value in the control of *D. abbreviatus*. Six of these materials (Nos. 1, 5, 6, 8, 9, and 10 in *Table 1*) were subjected to a persistence test. In this test, all but two of the materials failed to provide more than seven days' control. The two exceptions, carbaryl and Folimat, provided 94 and 88 per cent control, respectively, at the end of 14 days. Azinphosmethyl, the next best performer, provided 41 per cent control.

Only the data for the first two weeks of the test are considered valid for, while 280 mm (11 in.) of rainfall during the four weeks undoubtedly diminished the residues, excessive natural mortality occurring in the final two weeks nullified the performance of all materials. The test results revealed that azinphosmethyl, Supracide, parathion, and malathion will provide one week of control while carbaryl and Folimat may provide control beyond two weeks.

Since the emergence of adult weevils over a period of several months would require a pesticide that promised more than one week of effective control, azinphosmethyl, Supracide, parathion, and malathion would have to be used repeatedly to provide satisfactory control. Carbaryl and Folimat may be satisfactory but their persistence must be determined by further testing.

No feeding or oviposition occurred in the presence of azinphosmethyl, monocrotophos, Supracide, DDT, Folimat, or carbaryl during the three-day exposure period. Slight feeding but no oviposition was observed on foliage treated with the high rates of formetanate and malathion. Both feeding and oviposition occurred in the presence of all the remaining compounds, includ- in lead arsenate, and all were lethal to both sexes without partiality.

Wolcott (1948) reported that the effect of DDT was mostly that of a repellent. This may be so under natural field conditions where the beetle is unconfined, but since beetles can easily survive three days without food, the deaths that occurred while beetles were confined on the foliage in this test can be attributed to the toxic residues of the test chemical.

CONCLUSIONS

Under the conditions of the experiment, no material exhibited sufficient persistence to permit a Florida grower, wishing to employ foliar spraying as his sole method of weevil control, to succeed with a single application. For the express purpose of controlling *D. abbreviatus*, multiple applications may be required, a procedure having little economic appeal to growers.

Eventually, selection of materials may become more restrictive with evolution of a biological control programme that might consist of parasites or predators susceptible to some of the recommended pesticides. If current attempts to colonize the parasitic wasp *Tetrastichus haitiensis* Gahan in Florida are successful, this initial reliance on chemicals will diminish or be completely abandoned.

Until that time arrives, azinphosmethyl, dimethoate, parathion, and the high rate of malathion, when used for their recommended purposes, will augment a programme involving soil treatment and be of supplementary

benefit to growers when application abundance. In fact, carbophenoth Florida to non-bearing trees), and th also be selected by a grower for use traditional citrus pests with the kno to mitigate his weevil problem.

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benefit to growers when applications coincide with periods of adult beetle abundance. In fact, carbophenothion, oxydemetonmethyl (restricted in Florida to non-bearing trees), and the less effective rate of malathion could also be selected by a grower for use in his programmed spray for control of traditional citrus pests with the knowledge that these materials would help to mitigate his weevil problem.

Malathion, dimethoate, and carbaryl, materials with relatively low mammalian toxicity levels, can be suggested for use by home owners in beetle-infested residential areas.

SUMMARY

Ten of 24 candidate pesticides were found capable, as dilute foliar sprays, of providing complete kill of adult *Diaprepes abbreviatus* L. within 72 h. Of these, azinphosmethyl, dimethoate, parathion, and malathion are recommended for use on Florida citrus. The interval of effectiveness may be too brief to recommend their use in sprays as the sole method of control but they can supplement soil treatment and may be useful in an integrated control programme.

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